ISSN 1070-3632, Russian Journal of General Chemistry, 2007, Vol. 77, No. 8, pp. 1477–1479. © Pleiades Publishing, Ltd., 2007.
Original Russian Text © A.A. Prishchenko, M.V. Livantsov, O.P. Novikova, L.I. Livantsova, A.V. Maryashkin, E.R. Milaeva, 2007, published in Zhurnal Obshchei Khimii, 2007, Vol. 77, No. 8, pp. 1400–1402.

LETTERS TO THE EDITOR

Addition of Trimethylsilyl Esters of Trivalent Phosphorus Acids to Diethyl 3,5-Di-*tert*-butyl-4-hydroxybenzoylphosphonate

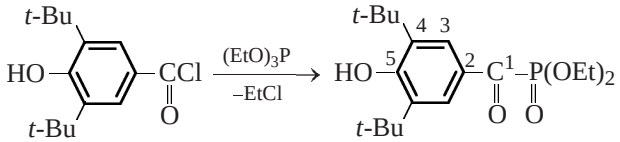
A. A. Prishchenko, M. V. Livantsov, O. P. Novikova, L. I. Livantsova, A. V. Maryashkin, and E. R. Milaeva

Lomonosov Moscow State University, Vorob'evy Gory, Moscow, 119992 Russia
e-mail: liv@org.chem.msu.ru

Received December 25, 2006

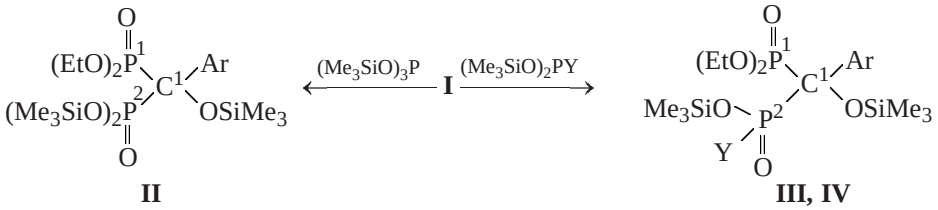
DOI: 10.1134/S107036320708035X

Derivatives of substituted unsymmetrical hydroxymethylenediphosphorus acids containing two phosphoryl groups with different extents of polarization are of interest as ligands and biologically active compounds [1]. Here we report on a facile route to new derivatives of unsymmetrical hydroxymethylenediphosphorus acids containing a 2,6-di-*tert*-butylphenol fragment starting from diethyl (3,5-di-*tert*-butyl-4-hydroxybenzoyl)phosphonate **I** detected previously as an intermediate [2]. Phosphonate **I** was prepared in a high yield by the reaction of triethyl phosphite with readily available 3,5-di-*tert*-butyl-4-hydroxybenzoyl chloride **A** [3].

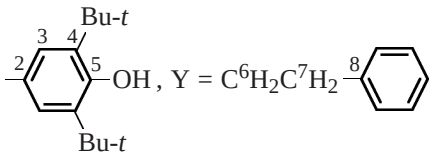


A **I**

Tris(trimethylsilyl) phosphite as well as functionalized trimethylsilyl phosphonites taken in excess readily add to the carbonyl group of α-keto phosphonate **I** with the formation of diphosphonate **II** and phosphonate–phosphinates **III** and **IV**, respectively, in high yields.



II **III, IV**

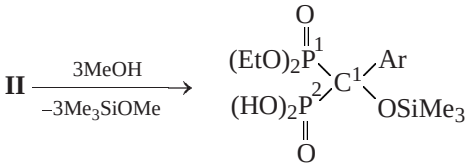
Ar = 

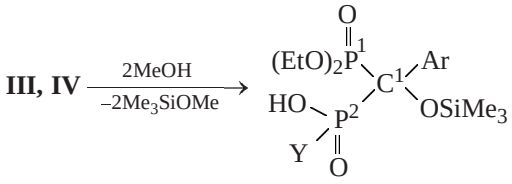
, Y = $C^6H_2C^7H_2$–

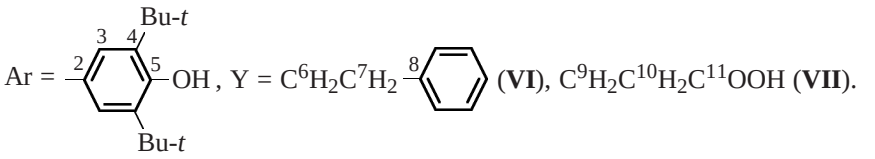
(**III**), $C^9H_2C^{10}H_2C^{11}OOSiMe_3$ (**IV**).

The reactions of diphosphonate **II** and phosphonate–phosphinates **III** and **IV** with excess methanol gave substituted hydroxymethylenediphosphorus acids **V**–**VII** in high yields. Acid **V** is obtained as white hygroscopic crystals decomposing on heating above 100°C, without definite melting point. Acids **VI** and **VII** are viscous oils.

Previously unknown hydroxymethylenediphosphoryl compounds **II**–**VII** containing a sterically







hindered phenolic fragment are promising complexing agents and antioxidants. The NMR spectra of **II**–**VII** contain characteristic signals of methylenediphosphoryl fragments $P^1C^1P^2$ together with the signals of substituted aromatic fragments and propionic acid moieties. The methylene protons of **III**, **IV**, **VI**, and **VII** give in the ^{1}H NMR spectra partly overlapping multiplets. In the ^{13}C NMR spectra of **III** and **VI**, the signals of the phenyl fragment overlap with the signals of C^2 and C^3 nuclei.

Diethyl (3,5-di-*tert*-butyl-4-hydroxybenzoyl)-phosphonate I. A mixture of 3.8 g of 3,5-di-*tert*-butyl-4-hydroxybenzoic acid and 8 ml of thionyl chloride in 10 ml of hexane was refluxed for 0.5 h, after which the solvent was distilled off in a vacuum, and the residue was kept in a vacuum (0.5 mm Hg) for 0.5 h. Then a solution of 4 g of triethyl phosphite in 10 ml of methylene chloride was added with stirring and cooling (10°C) to a solution of chloride **A** in 15 ml of methylene chloride. The mixture was stirred for 0.5 h and then heated to reflux, after which the solvent was distilled off, 15 ml of hexane was added to the residue, and the mixture was cooled to –10°C. The oil that separated out was washed with cold hexane and kept in a vacuum (0.5 mm Hg) for 1 h to obtain 4.6 g (81%) of phosphonate **I** as oil. ^{1}H NMR spectrum, δ, ppm: 1.32 t (CH_3CH_2O, $^3J_{HH}$ 8 Hz), 1.40 s (Me_3C), 4.15–4.25 m (CH_2O), 6.30 br.s (OH), 8.16 s (C_6H_2). ^{13}C NMR spectrum, δ_C, ppm: 16.34 d (CH_3CH_2O, $^3J_{PC}$ 6 Hz), 29.97 s (Me_3C), 34.43 s (Me_3C), 63.52 d (CH_2O, $^2J_{PC}$ 8 Hz), 196.61 d (C^1, $^1J_{PC}$ 171 Hz), 129.44 s (C^2), 128.07 s (C^3), 136.64 s (C^4), 160.39 s (C^5). ^{31}P NMR spectrum, δ_P, ppm: 0.05 s. Found, %: C 61.48; H 8.35. $C_{19}H_{31}O_5P$. Calculated, %: C 61.61; H 8.43.

Bis(trimethylsilyl) (3,5-di-*tert*-butyl-4-hydroxyphenyl)(trimethylsiloxy)(diethoxyphosphoryl)methylphosphonate II. A solution of 10 g of tris(trimethylsilyl) phosphite in 5 ml of methylene chloride was added with stirring and cooling (10°C) to a solution of 4.6 g of phosphonate **I** in 10 ml of methylene chloride,. The mixture was refluxed for 2 h and kept for 24 h, after which the solvent was distilled off, and the residue was left for 24 h. Then 15 ml of hexane was added to the residue, and the resulting solution was cooled to –5°C. The precipitated white crystals were filtered off and kept in a vacuum (0.5 mm Hg) for 1 h to give 7.2 g (87%) of phosphonate **II**, mp 110°C. ^{1}H NMR spectrum, δ, ppm: –0.03 and 0.11 s (Me_3SiOP), 0.15 s (Me_3SiOC), 1.01 t and 1.12 t ($CH_3 \cdot CH_2O$, $^3J_{HH}$ 7 Hz), 1.32 s (Me_3C), 3.6–4.0 m (CH_2O), 5.14 br. s (OH), 7.54 s (C_6H_2). ^{13}C NMR spectrum, δ_C, ppm: 0.77 s and 0.96 s (Me_3SiOP), 2.57 s (Me_3SiOC), 16.12 d and 16.16 d (CH_3CH_2O, $^3J_{PC}$ 6 Hz), 30.29 s (Me_3C), 34.42 s (Me_3C), 62.77 d and 63.09 d (CH_2O, $^2J_{PC}$ 8 Hz), 79.72 d.d [C^1, $^1J_{P^1C}$ 151 Hz, $^1J_{P^2C}$ 163 Hz], 126.61 s (C^2), 124.28 t [C^3, $^3J_{P^1C}$ = $^3J_{P^2C}$ 4 Hz], 134.39 s (C^4), 153.10 s (C^5). ^{31}P NMR spectrum, δ_P, ppm: 16.92 d (P^1), –0.58 d (P^2), $^2J_{PP}$ 45.4 Hz. Found, %: C 49.92; H 8.68. $C_{28}H_{58}O_8P_2Si_3$. Calculated, %: C 50.27; H 8.74.

Compounds **III** and **IV** were prepared similarly. These compounds are extremely readily hydrolyzed,

and therefore they were analyzed in the form of the corresponding acids **VI** and **VII**.

Trimethylsilyl [(3,5-di-*tert*-butyl-4-hydroxyphenyl)(trimethylsiloxy)(diethoxyphosphoryl)methyl](2-phenylethyl)phosphinate III. Yield 85%, oil. ^{1}H NMR spectrum, δ, ppm: –0.05 (Me_3SiOP), 0.17 s (Me_3SiOC), 1.1–1.15 m (CH_3CH_2O), 1.37 s (Me_3C), 3.6–4.0 m (CH_2O), 5.75 br.s (OH), 7.0–7.5 m (C_6H_2, C_6H_5). ^{13}C NMR spectrum, δ_C, ppm: 0.62 s and 0.96 s (Me_3SiOP), 2.37 s (Me_3SiOC), 15.6–15.8 m ($CH_3 \cdot CH_2O$), 30.03 s (Me_3C), 34.35 s (Me_3C), 62.5–63.3 m (CH_2O), 81.25 d.d [C^1, $^1J_{P^1C}$ 147 Hz, $^1J_{P^2C}$ 102 Hz], 135.58 s (C^4), 153.30 s (C^5), 32.08 d (C^6, $^1J_{PC}$ 93 Hz), 27.82 d (C^7, $^2J_{PC}$ 3 Hz), 141.37 d (C^8, $^3J_{PC}$ 16 Hz). ^{31}P NMR spectrum, δ_P, ppm: 17.14 d (P^1), 39.08 d (P^2), $^2J_{PP}$ 43.7 Hz.

Trimethylsilyl [(3,5-di-*tert*-butyl-4-hydroxyphenyl)(trimethylsiloxy)(diethoxyphosphoryl)methyl][2-(trimethylsiloxycarbonyl)ethyl]phosphinate IV. Yield 90%, oil. ^{1}H NMR spectrum, δ, ppm: 0.16 s [$Me_3SiOC(O)$], 0.05 s (Me_3SiOP), 0.26 s (Me_3SiOC), 1.0–1.1 m (CH_3CH_2O), 1.28 s (Me_3C), 3.7–4.3 m (CH_2O), 5.30 br.s (OH), 7.54 s (C_6H_2). ^{13}C NMR spectrum, δ_C, ppm: 0.67 s [$Me_3SiOC(O)$], 0.99 s (Me_3SiOP), 2.32 s (Me_3SiOC), 15.8–16.0 m ($CH_3 \cdot CH_2O$), 30.03 s (Me_3C), 34.32 s (Me_3C), 62.5–63.0 m (CH_2O), 81.25 d.d [C^1, $^1J_{P^1C}$ 148 Hz, $^1J_{P^2C}$ 106 Hz], 126.99 s (C^2), 123.62 s (C^3), 135.21 s (C^4), 153.42 s (C^5), 22.44 d (C^9, $^1J_{PC}$ 98 Hz), 28.50 s (C^{10}), 172.45 d (C^{11}, $^3J_{PC}$ 19 Hz). ^{31}P NMR spectrum, δ_P, ppm: 17.15 d (P^1), 38.95 d (P^2), $^2J_{PP}$ 43.7 Hz.

(3,5-Di-*tert*-butyl-4-hydroxyphenyl)hydroxy(diethoxyphosphoryl)methylphosphonic acid V. Diphosphonate **II**, 7.2 g, was added to 30 ml of methanol with stirring and cooling to 10°C. The mixture was heated to reflux, the solvent was distilled off, and the residue was washed with hexane and kept in a vacuum (1 mm Hg) for 1 h to obtain 4.4 g (91%) of acid **IV** as white crystals. ^{1}H NMR spectrum, δ, ppm: 1.00 and 1.17 t (CH_3CH_2O, $^3J_{HH}$ 8 Hz), 1.39 s (Me_3C), 3.7–4.2 m (CH_2O), 7.58 s (C_6H_2). ^{13}C NMR spectrum, δ_C, ppm: 16.45 d and 16.73 d (CH_3CH_2O, $^3J_{PC}$ 6 Hz), 30.92 s (Me_3C), 35.08 s (Me_3C), 63.23 d and 63.31 d (CH_2O, $^2J_{PC}$ 8 Hz), 76.54 t [C^1, $^1J_{P^1C}$ = $^1J_{P^2C}$ 146 Hz], 127.41 s (C^2), 123.86 s (C^3), 137.76 s (C^4), 153.16 s (C^5). ^{31}P NMR spectrum, δ_P, ppm: 18.54 d (P^1), 14.95 d (P^2), $^2J_{PP}$ 38.9 Hz. Found, %: C 50.07; H 7.52. $C_{19}H_{34}O_8P_2$. Calculated, %: C 50.44; H 7.57.

Acids **VI** and **VII** were prepared similarly.

[(3,5-Di-*tert*-butyl-4-hydroxyphenyl)hydroxy(diethoxyphosphoryl)methyl](2-phenylethyl)phosphinic acid VI. Yield 92%, oil. ^{1}H NMR spectrum, δ, ppm: 1.10–1.15 m (CH_3CH_2O), 1.32 s (Me_3C), 3.7–4.2 m (CH_2O), 7.0–7.7 m (C_6H_2, C_6H_5). ^{13}C NMR spectrum, δ_C, ppm: 16.4–16.6 m (CH_3CH_2O), 30.85 s (Me_3C), 35.11 s (Me_3C), 63.5–64.0 m (CH_2O), 77.77 d.d [C^1, $^1J_{P^1C}$ 148 Hz, $^1J_{P^2C}$ 96 Hz], 138.15 s (C^4), 153.52 s (C^5), 31.66 (C^6, $^1J_{PC}$ 94 Hz), 27.84 s (C^7), 142.50 d (C^8, $^3J_{PC}$ 15 Hz). ^{31}P NMR spectrum, δ_P, ppm: 17.97 d (P^1), 43.59 d (P^2), $^2J_{PP}$ 32.4 Hz. Found, %: C 59.65; H 7.74. $C_{27}H_{42}O_7P_2$. Calculated, %: C 59.99; H 7.83.

[(3,5-Di-*tert*-butyl-4-hydroxyphenyl)hydroxy(diethoxyphosphoryl)methyl](2-carboxyethyl)phosphinic acid VII. Yield 92%, oil. ^{1}H NMR spectrum, δ, ppm: 1.0–1.15 m (CH_3CH_2O), 1.32 s (Me_3C), 3.7–4.3 m (CH_2O), 7.53 s (C_6H_2). ^{13}C NMR spectrum, δ_C, ppm: 16.4–16.6 m (CH_3CH_2O), 30.78 s (Me_3C), 35.06 s (Me_3C), 62.5–63.0 m (CH_2O), 77.70 d.d [C^1, $^1J_{P^1C}$ 153 Hz, $^1J_{P^2C}$ 93 Hz], 126.36 s (C^2), 123.84 (C^3), 138.05 s (C^4), 153.45 s (C^5), 22.21 d (C^9, $^1J_{PC}$ 94 Hz), 26.83 s (C^{10}), 173.18 d (C^{11}, $^3J_{PC}$ 15 Hz). ^{31}P NMR spectrum, δ_P, ppm: 17.93 d (P^1), 43.10 d (P^2), $^2J_{PP}$ 35.6 Hz. Found, %: C 51.59; H 7.46. $C_{22}H_{38} \cdot O_9P_2$. Calculated, %: C 51.97; H 7.57.

The NMR spectra were recorded on a Bruker Avance 400 spectrometer, solvents $CDCl_3$ for **I**–**IV** and $(CD_3)_2SO$ for **V**–**VII**, references TMS (^{1}H and ^{13}C) and 85% H_3PO_4 in D_2O (^{31}P).

ACKNOWLEDGMENTS

The study was financially supported by the Russian Foundation for Basic Research (project nos. 05-03-32864 and 06-03-32731).

REFERENCES

1. Ebetino, F.H., *Phosphorus, Sulfur, Silicon, Relat Elem.*, 1999, vols. 144–146, p. 9.
2. Prishchenko, A.A., Livantsov, M.V., Novikova, O.P., Livantsova, L.I., Maryashkin, A.V., and Milaeva, E.R., *Zh. Obshch. Khim.*, 2007, vol. 77, no. 8, p. 1397.
3. Ivakhnenko, E.P., Shif, A.I., Prokof'ev, A.I., Olekhnovich, L.P., and Minkin, V.I., *Zh. Org. Khim.*, 1989, vol. 25, no. 2, p. 357.